Northeastern University

EECE 7205 Fundamentals of Computer Engineering

Project 2

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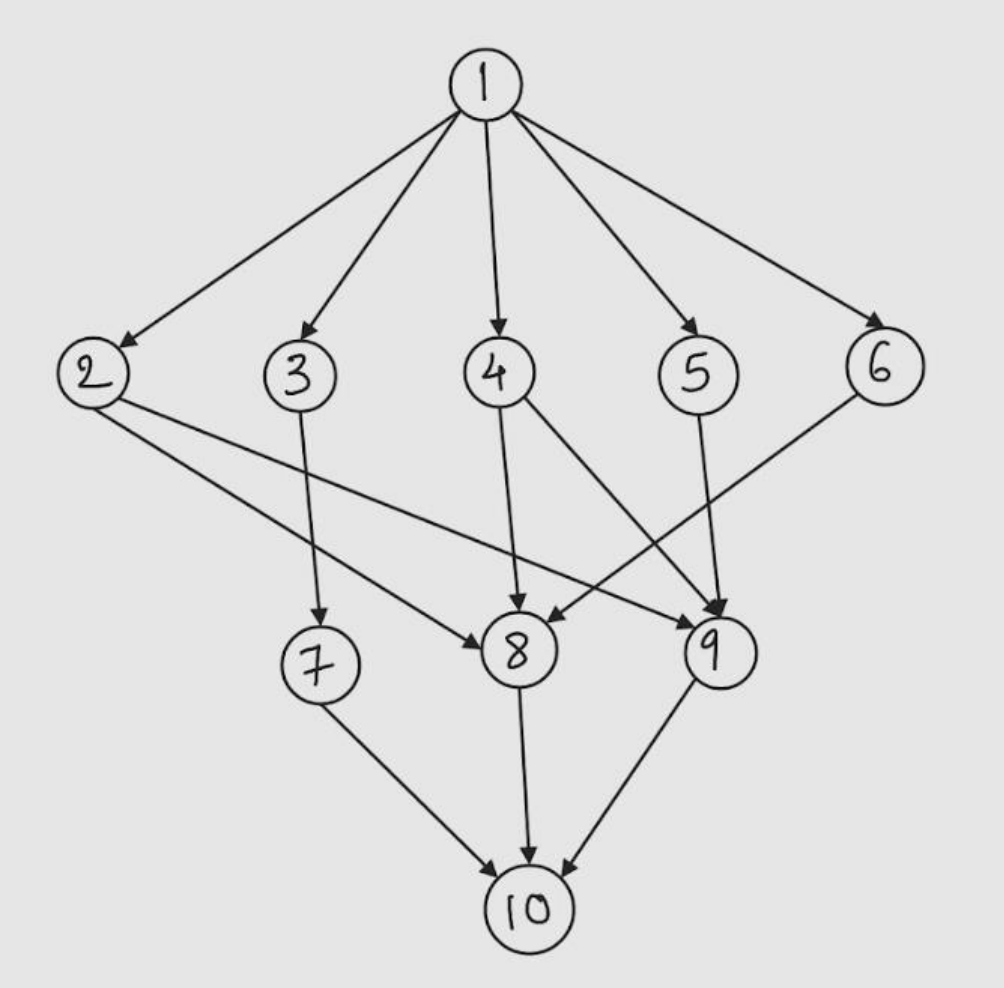
Task Graph 1



$$T_{max} = 27 \qquad \begin{cases} T^S = 3; \\ T^C = 1; \\ T^R = 1; \end{cases} \qquad \begin{cases} P_1 = 1; \\ P_2 = 2; \\ P_3 = 4; \\ P_s = 0.5; \end{cases}$$

Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2

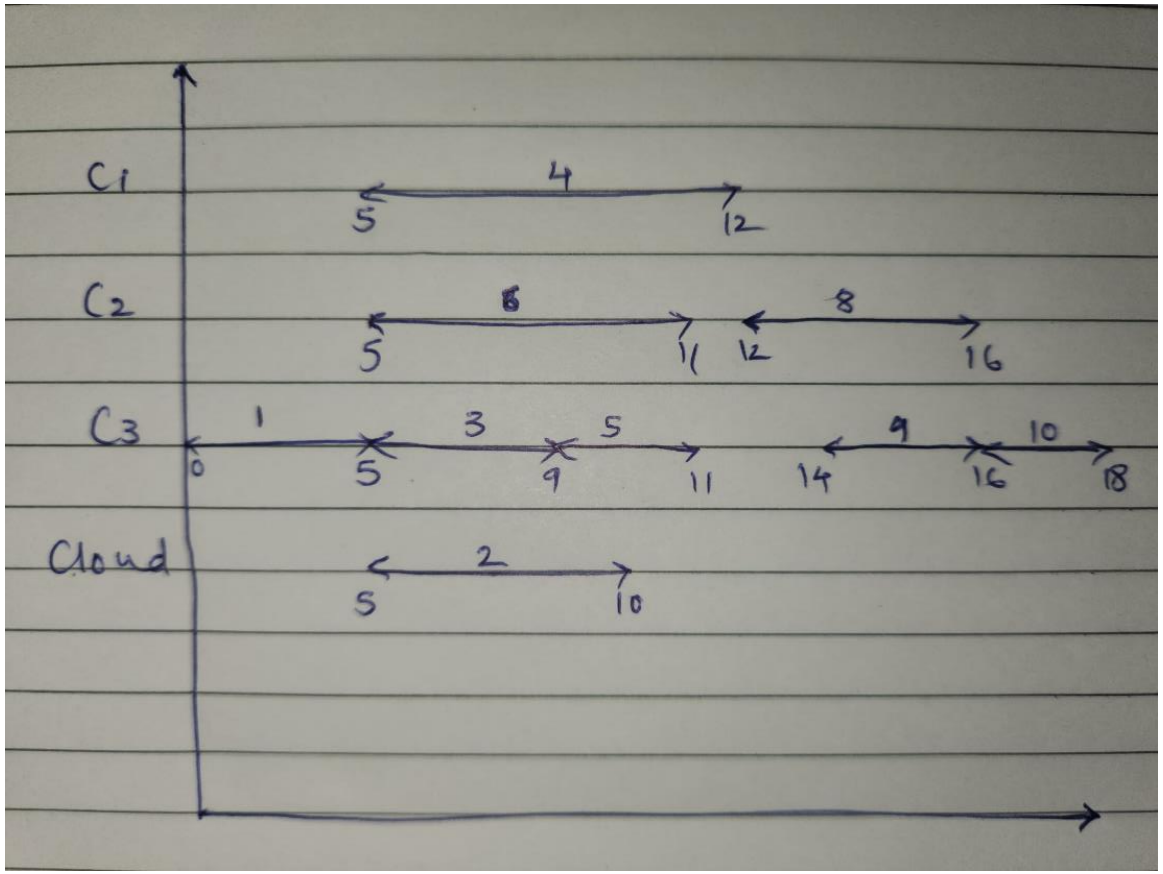
Output for Initial Scheduling

```
Initial schedule:
Task1: Local Core number 3, The start time is: 0,The finish time is: 5
Task3: Local Core number 3, The start time is: 5,The finish time is: 9
Task2: Cloud, The start time is: 5,The finish time is: 10
Task6: Local Core number 2, The start time is: 5,The finish time is: 11
Task4: Local Core number 1, The start time is: 5,The finish time is: 12
Task5: Local Core number 3, The start time is: 9,The finish time is: 11
Task7: Local Core number 3, The start time is: 11,The finish time is: 14
Task8: Local Core number 2, The start time is: 12,The finish time is: 16
Task9: Local Core number 3, The start time is: 14,The finish time is: 16
Task10: Local Core number 3, The start time is: 16,The finish time is: 18
 The total energy is: 100.5
 The completion time is: 18
```

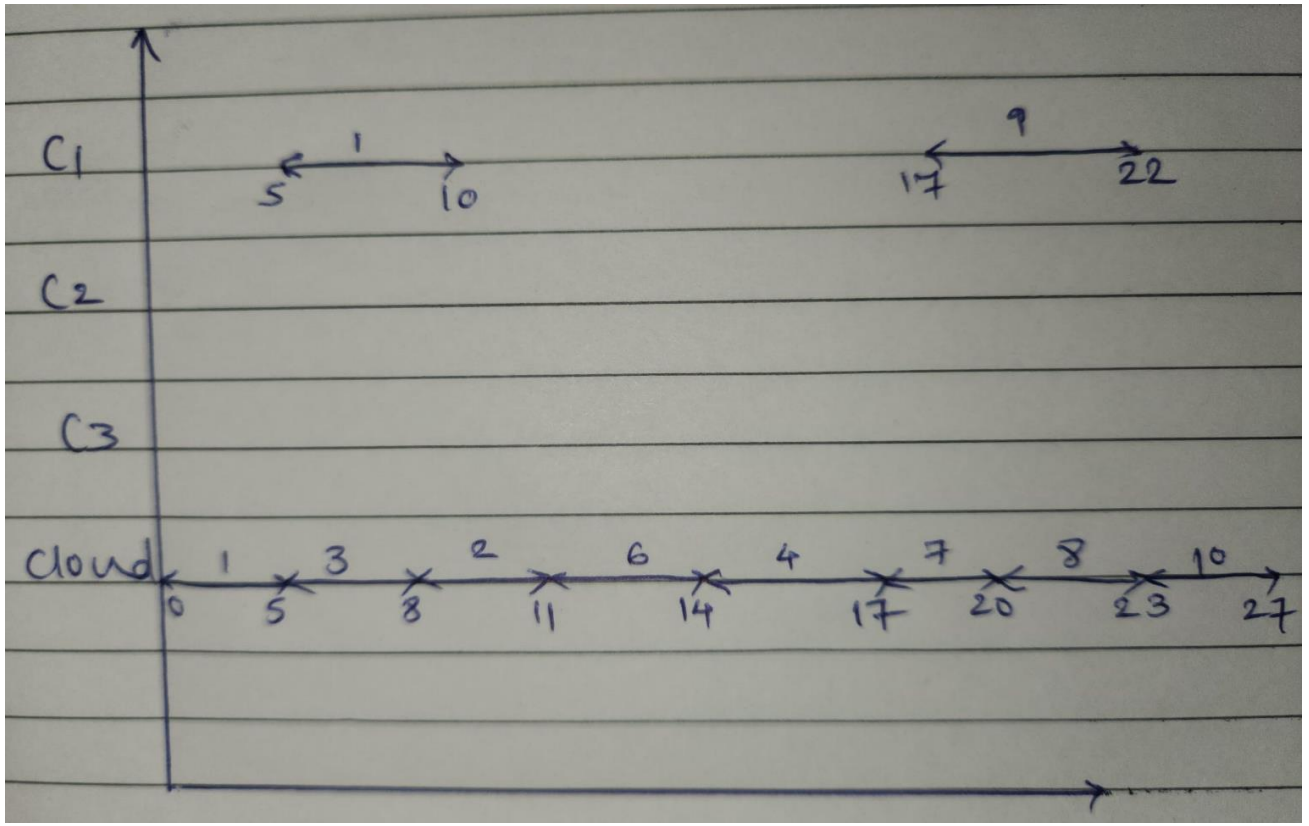
Output for final Scheduling

```
After Task Migration:
Task1: Cloud, The start time is: 0,The finish time is: 5
Task3: Cloud, The start time is: 3,The finish time is: 8
Task2: Cloud, The start time is: 6,The finish time is: 11
Task6: Cloud, The start time is: 9,The finish time is: 14
Task4: Cloud, The start time is: 12,The finish time is: 17
Task5: Local Core number 1, The start time is: 5,The finish time is: 10
Task7: Cloud, The start time is: 15,The finish time is: 20
Task8: Cloud, The start time is: 18,The finish time is: 23
Task9: Local Core number 1, The start time is: 17,The finish time is: 22
Task10: Cloud, The start time is: 22,The finish time is: 27
 The total energy is: 22
 The completion time is: 27
The running time of task migration of Graph 1 is 13 ms
```

Task Graphs



Initial Scheduling



Final Scheduling: Some overlapping can be seen between the time frames of cloud in the output. These overlaps are not shown in the graph above

Manual Calculation of Energy Consumption

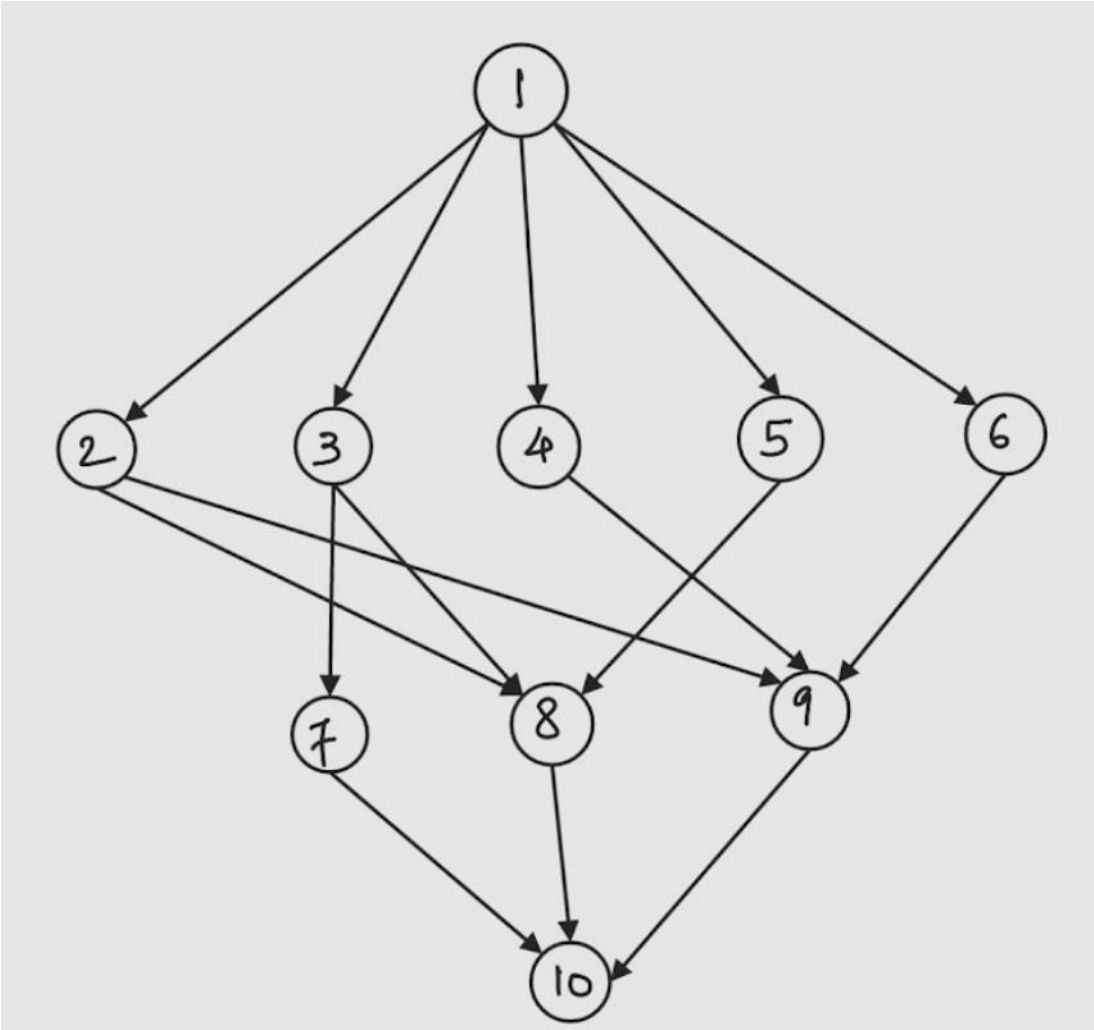
Task	Power	Time	Energy
1	4	5	20
2	4	4	16
3	0.5	5	2.5
4	2	6	12
5	1	7	8
6	4	2	6
7	4	3	12
8	2	4	8
9	4	2	8
10	4	2	8

Initial: Total Energy =100.5

Task	Power	Time	Energy
1	0.5	5	2.5
2	0.5	5	2.5
3	0.5	5	2.5
4	0.5	5	2.5
5	0.5	5	2.5
6	1	5	5
7	0.5	5	2.5
8	0.5	5	2.5
9	1	5	5
10	0.5	5	2.5

Final: Total Energy=30

Task Graph 2



$$T_{max} = 27$$

$$\begin{cases} T^S = 3; \\ T^C = 1; \\ T^R = 1; \end{cases} \qquad \begin{cases} P_1 = 1; \\ P_2 = 2; \\ P_3 = 4; \\ P_s = 0.5; \end{cases}$$

Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2

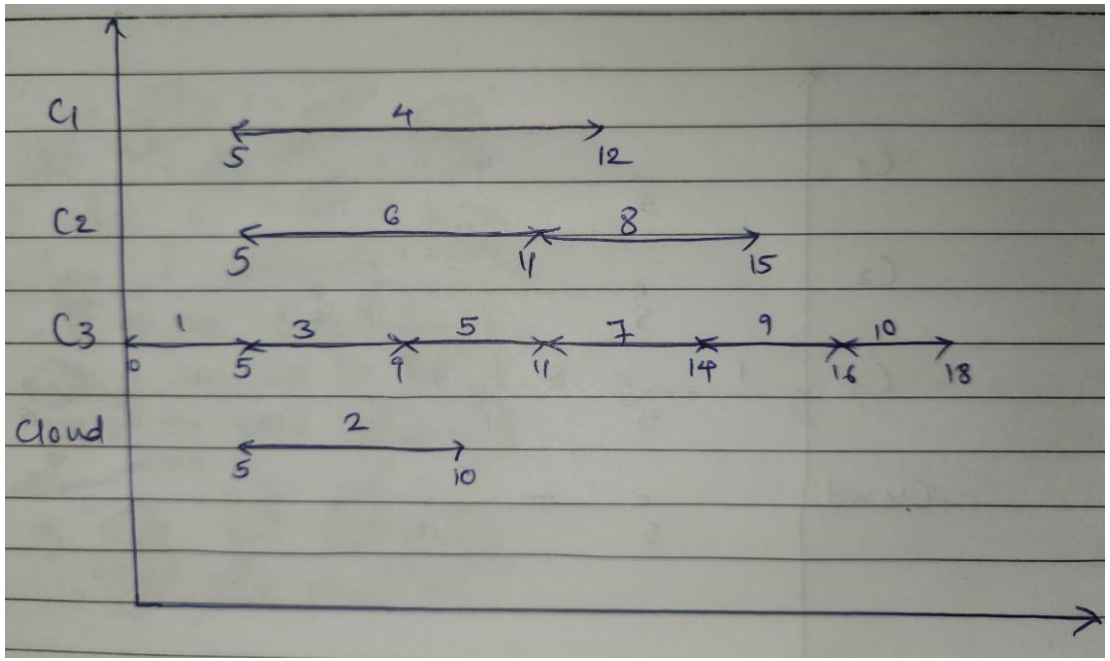
Output for Initial Scheduling

```
Initial schedule:
Task1: Local Core number 3, The start time is: 0,The finish time is: 5
Task3: Local Core number 3, The start time is: 5,The finish time is: 9
Task2: Cloud, The start time is: 5,The finish time is: 10
Task6: Local Core number 2, The start time is: 5,The finish time is: 11
Task4: Local Core number 1, The start time is: 5,The finish time is: 12
Task5: Local Core number 3, The start time is: 9,The finish time is: 11
Task7: Local Core number 3, The start time is: 11,The finish time is: 14
Task8: Local Core number 2, The start time is: 11,The finish time is: 15
Task9: Local Core number 3, The start time is: 14,The finish time is: 16
Task10: Local Core number 3, The start time is: 16,The finish time is: 18
 The total energy is: 100.5
 The completion time is: 18
```

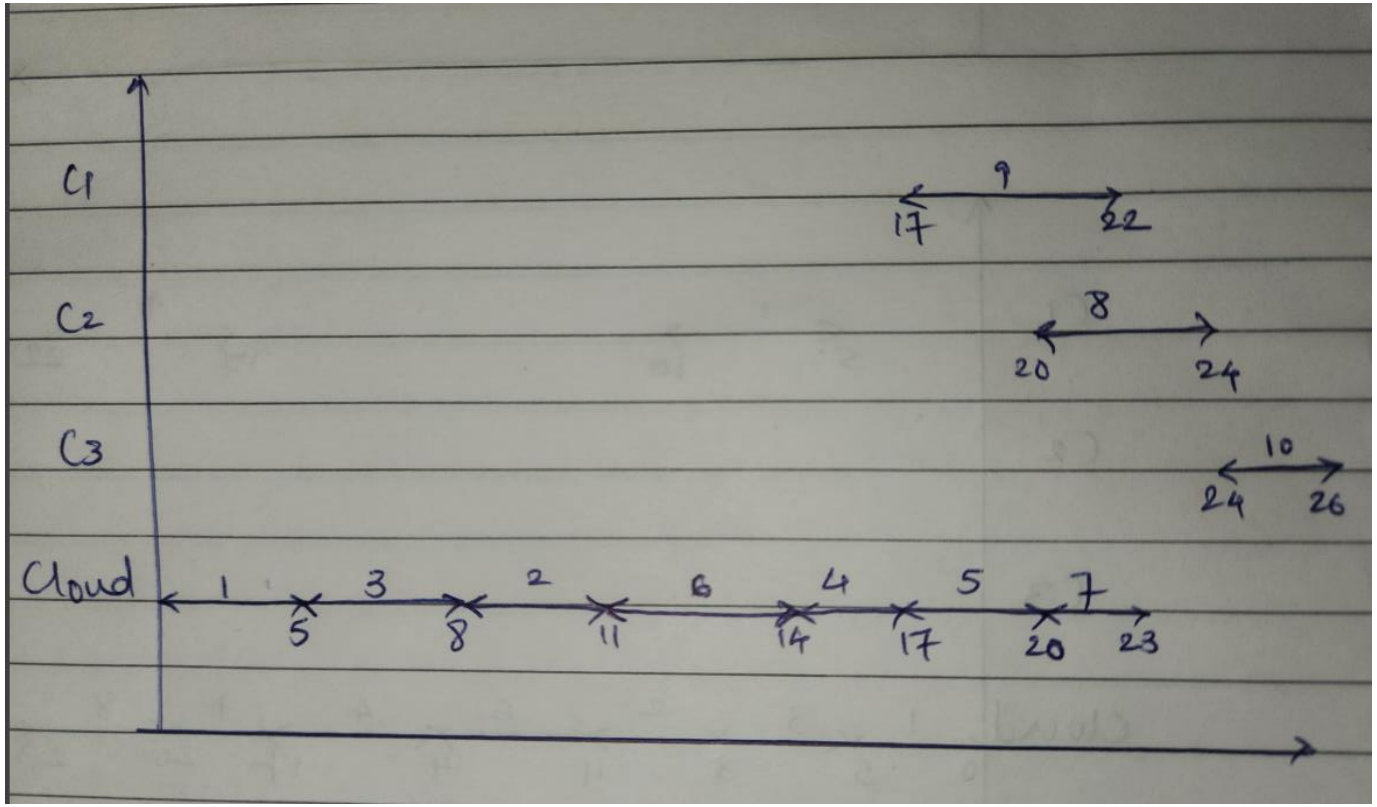
Output for final Scheduling

```
After Task Migration:
Task1: Cloud, The start time is: 0,The finish time is: 5
Task3: Cloud, The start time is: 3,The finish time is: 8
Task2: Cloud, The start time is: 6,The finish time is: 11
Task6: Cloud, The start time is: 9,The finish time is: 14
Task4: Cloud, The start time is: 12,The finish time is: 17
Task5: Cloud, The start time is: 15,The finish time is: 20
Task7: Cloud, The start time is: 18,The finish time is: 23
Task8: Local Core number 2, The start time is: 20,The finish time is: 24
Task9: Local Core number 1, The start time is: 17,The finish time is: 22
Task10: Local Core number 3, The start time is: 24,The finish time is: 26
 The total energy is: 31.5
 The completion time is: 26
The running time of task migration of Graph 1 is 5 ms
```

Task Graphs



Initial Scheduling



Final Scheduling: Some overlapping can be seen between the time frames of cloud in the output. These overlaps are not shown in the graph above

Manual Calculation of Energy Consumption

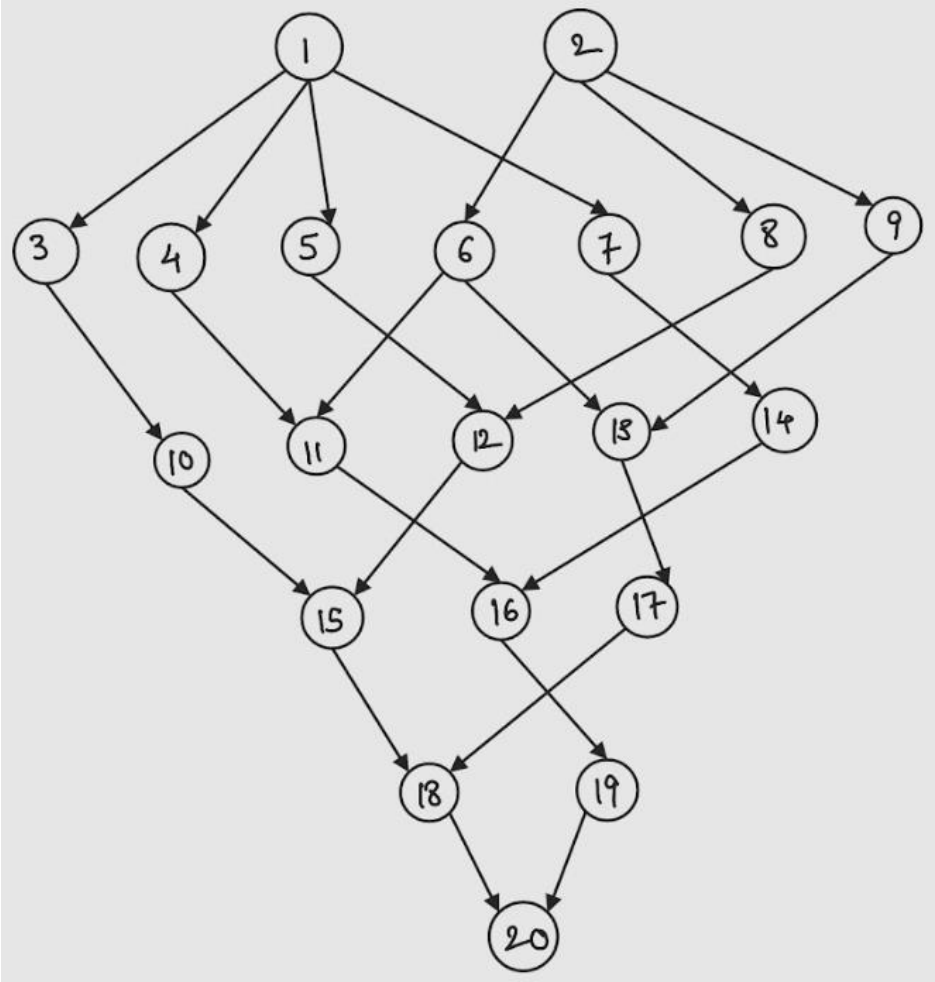
Task	Power	Time	Energy
1	4	5	20
2	4	4	16
3	0.5	5	2.5
4	2	6	12
5	1	7	7
6	4	2	8
7	4	2	8
8	2	3	6
9	4	2	8
10	4	2	8

Initial: Total Energy =100.5

Task	Power	Time	Energy
1	0.5	5	2.5
2	0.5	5	2.5
3	0.5	5	2.5
4	0.5	5	2.5
5	0.5	5	2.5
6	0.5	5	2.5
7	0.5	5	2.5
8	2	4	8
9	1	5	5
10	4	2	8

Final: Total Energy=38.5

Task Graph 3



Task	Core 1	Core 2	Core 3
1	9	7	5
2	8	6	5
3	6	5	4
4	7	5	3
5	5	4	2
6	7	6	4
7	8	5	3
8	6	4	2
9	5	3	2
10	7	4	2

Task	Core 1	Core 2	Core 3
11	7	6	5
12	8	7	4
13	9	8	6
14	6	6	5
15	4	3	2
16	6	5	4
17	8	7	6
18	5	4	3
19	5	4	2
20	9	8	6

$$T_{max} = 27 \qquad \begin{cases} T^S = 3; \\ T^C = 2; \\ T^R = 1; \end{cases} \qquad \begin{cases} P_1 = 2; \\ P_2 = 3; \\ P_3 = 5; \\ P_s = 1.5; \end{cases}$$

Output for Initial Scheduling

```
Initial schedule:
Task2: Local Core number 3, The start time is: 0,The finish time is: 5
Task1: Cloud, The start time is: 0,The finish time is: 6
Task6: Local Core number 3, The start time is: 5,The finish time is: 9
Task9: Local Core number 2, The start time is: 5,The finish time is: 8
Task4: Cloud, The start time is: 3,The finish time is: 9
Task7: Local Core number 3, The start time is: 9,The finish time is: 12
Task13: Cloud, The start time is: 9,The finish time is: 15
Task8: Local Core number 1, The start time is: 5,The finish time is: 11
Task5: Local Core number 2, The start time is: 8,The finish time is: 12
Task3: Local Core number 3, The start time is: 12,The finish time is: 16
Task11: Local Core number 1, The start time is: 11,The finish time is: 18
Task14: Local Core number 2, The start time is: 12,The finish time is: 18
Task12: Cloud, The start time is: 12,The finish time is: 18
Task10: Local Core number 3, The start time is: 16,The finish time is: 18
Task17: Cloud, The start time is: 15,The finish time is: 21
Task16: Local Core number 3, The start time is: 18,The finish time is: 22
Task15: Local Core number 2, The start time is: 18,The finish time is: 21
Task18: Local Core number 2, The start time is: 21,The finish time is: 25
Task19: Local Core number 3, The start time is: 22,The finish time is: 24
Task20: Local Core number 3, The start time is: 25,The finish time is: 31
 The total energy is: 258.5
 The completion time is: 31
```

Output for final Scheduling

```
After all of Task Migration:
Task2: Local Core number 3, The start time is: 0,The finish time is: 5
Task1: Cloud, The start time is: 0,The finish time is: 6
Task6: Local Core number 3, The start time is: 5,The finish time is: 9
Task9: Local Core number 2, The start time is: 5,The finish time is: 8
Task4: Cloud, The start time is: 3,The finish time is: 9
Task7: Cloud, The start time is: 6,The finish time is: 12
Task13: Cloud, The start time is: 9,The finish time is: 15
Task8: Local Core number 3, The start time is: 9,The finish time is: 11
Task5: Local Core number 1, The start time is: 6,The finish time is: 11
Task3: Local Core number 3, The start time is: 11,The finish time is: 15
Task11: Local Core number 1, The start time is: 11,The finish time is: 18
Task14: Local Core number 2, The start time is: 12,The finish time is: 18
Task12: Cloud, The start time is: 12,The finish time is: 18
Task10: Local Core number 3, The start time is: 15,The finish time is: 17
Task17: Cloud, The start time is: 15,The finish time is: 21
Task16: Local Core number 3, The start time is: 18,The finish time is: 22
Task15: Cloud, The start time is: 18,The finish time is: 24
Task18: Cloud, The start time is: 21,The finish time is: 27
Task19: Local Core number 3, The start time is: 22,The finish time is: 24
Task20: Cloud, The start time is: 24,The finish time is: 30
 The total energy is: 206.5
 The completion time is: 30
The running time of initial schedule of Graph 2 is 43 ms
```

Manual Calculation of Energy Consumption: Initial

Task	Power	Time	Energy
1	5	5	25
2	1.5	6	9
3	5	4	20
4	3	3	9
5	1.5	6	9
6	1.5	3	4.5
7	2	6	12
8	5	6	30
9	3	4	12
10	5	4	20

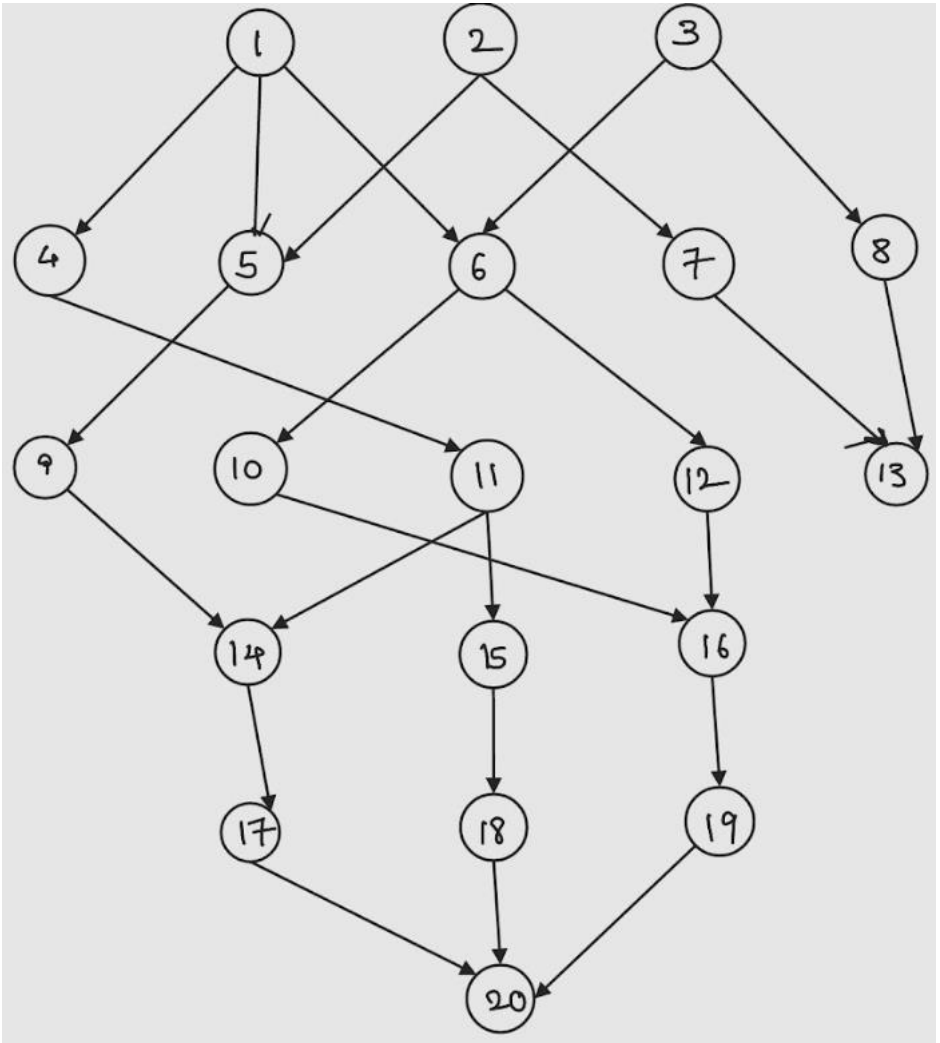
Task	Power	Time	Energy
11	2	7	14
12	3	6	18
13	1.5	2	3
14	1.5	6	9
15	5	4	20
16	3	3	9
17	3	4	12
18	5	3	15
19	5	6	30
20	5	6	30

Manual Calculation of Energy Consumption: Final

Task	Power	T3ime	Energy
1	5	5	25
2	1.5	6	9
3	5	4	20
4	3	3	9
5	1.5	6	9
6	1.5	6	9
7	5	5	25
8	2	4	8
9	5	4	20
10	2	6	12

Task	Power	Time	Energy
11	1.5	3	4.5
12	5	6	30
13	2	4	8
14	3	6	18
15	1.5	3	4.5
16	5	5	25
17	1.5	6	9
18	5	4	20
19	1.5	3	4.5
20	1.5	6	9

Task Graph 4



Task	Core 1	Core 2	Core 3	Task	Core 1	Core 2	Core 3
1	9	7	5	11	7	6	5
2	8	6	5	12	8	7	4
3	6	5	4	13	9	8	6
4	7	5	3	14	6	6	5
5	5	4	2	15	4	3	2
6	7	6	4	16	6	5	4
7	8	5	3	17	8	7	6
8	6	4	2	18	5	4	3
9	5	3	2	19	5	4	2
10	7	4	2	20	9	8	6

$$T_{max} = 27 \qquad \begin{cases} T^S = 3; \\ T^C = 2; \\ T^R = 1; \end{cases} \qquad \begin{cases} P_1 = 2; \\ P_2 = 3; \\ P_3 = 5; \\ P_s = 1.5; \end{cases}$$

Output for Initial Scheduling

```
Initial schedule:
Task1: Local Core number 3, The start time is: 0,The finish time is: 5
Task2: Local Core number 2, The start time is: 0,The finish time is: 6
Task3: Local Core number 1, The start time is: 0,The finish time is: 6
Task4: Local Core number 3, The start time is: 5,The finish time is: 8
Task6: Local Core number 2, The start time is: 6,The finish time is: 12
Task5: Local Core number 3, The start time is: 8,The finish time is: 10
Task11: Cloud, The start time is: 8,The finish time is: 14
Task9: Local Core number 3, The start time is: 10,The finish time is: 12
Task12: Local Core number 3, The start time is: 12,The finish time is: 16
Task14: Cloud, The start time is: 12,The finish time is: 18
Task10: Local Core number 2, The start time is: 12,The finish time is: 16
Task16: Local Core number 3, The start time is: 16,The finish time is: 20
Task15: Local Core number 1, The start time is: 14,The finish time is: 18
Task17: Cloud, The start time is: 16,The finish time is: 22
Task7: Local Core number 2, The start time is: 16,The finish time is: 21
Task8: Local Core number 3, The start time is: 20,The finish time is: 22
Task18: Local Core number 1, The start time is: 18,The finish time is: 23
Task19: Local Core number 3, The start time is: 22,The finish time is: 24
Task13: Cloud, The start time is: 22,The finish time is: 28
Task20: Local Core number 3, The start time is: 24,The finish time is: 30
 The total energy is: 261
 The completion time is: 30
```

Output for final Scheduling

```
After all of Task Migration:
Task1: Cloud, The start time is: 0,The finish time is: 6
Task2: Cloud, The start time is: 3,The finish time is: 9
Task3: Local Core number 1, The start time is: 0,The finish time is: 6
Task4: Cloud, The start time is: 6,The finish time is: 12
Task6: Local Core number 1, The start time is: 6,The finish time is: 13
Task5: Local Core number 3, The start time is: 9,The finish time is: 11
Task11: Cloud, The start time is: 9,The finish time is: 15
Task9: Cloud, The start time is: 12,The finish time is: 18
Task12: Local Core number 3, The start time is: 13,The finish time is: 17
Task14: Cloud, The start time is: 15,The finish time is: 21
Task10: Local Core number 2, The start time is: 13,The finish time is: 17
Task16: Local Core number 2, The start time is: 17,The finish time is: 22
Task15: Local Core number 1, The start time is: 15,The finish time is: 19
Task17: Cloud, The start time is: 18,The finish time is: 24
Task7: Cloud, The start time is: 21,The finish time is: 27
Task8: Local Core number 3, The start time is: 17,The finish time is: 19
Task18: Local Core number 1, The start time is: 19,The finish time is: 24
Task19: Local Core number 3, The start time is: 22,The finish time is: 24
Task13: Cloud, The start time is: 24,The finish time is: 30
Task20: Local Core number 3, The start time is: 24,The finish time is: 30
 The total energy is: 191.5
 The completion time is: 30
The running time of initial schedule of Graph 2 is 76 ms
```

Manual Calculation of Energy Consumption: Initial

Task	Power	Time	Energy
1	5	5	25
2	3	6	18
3	2	6	12
4	5	3	15
5	3	6	18
6	5	6	30
7	1.5	2	3
8	5	4	20
9	5	6	30
10	1.5	4	6

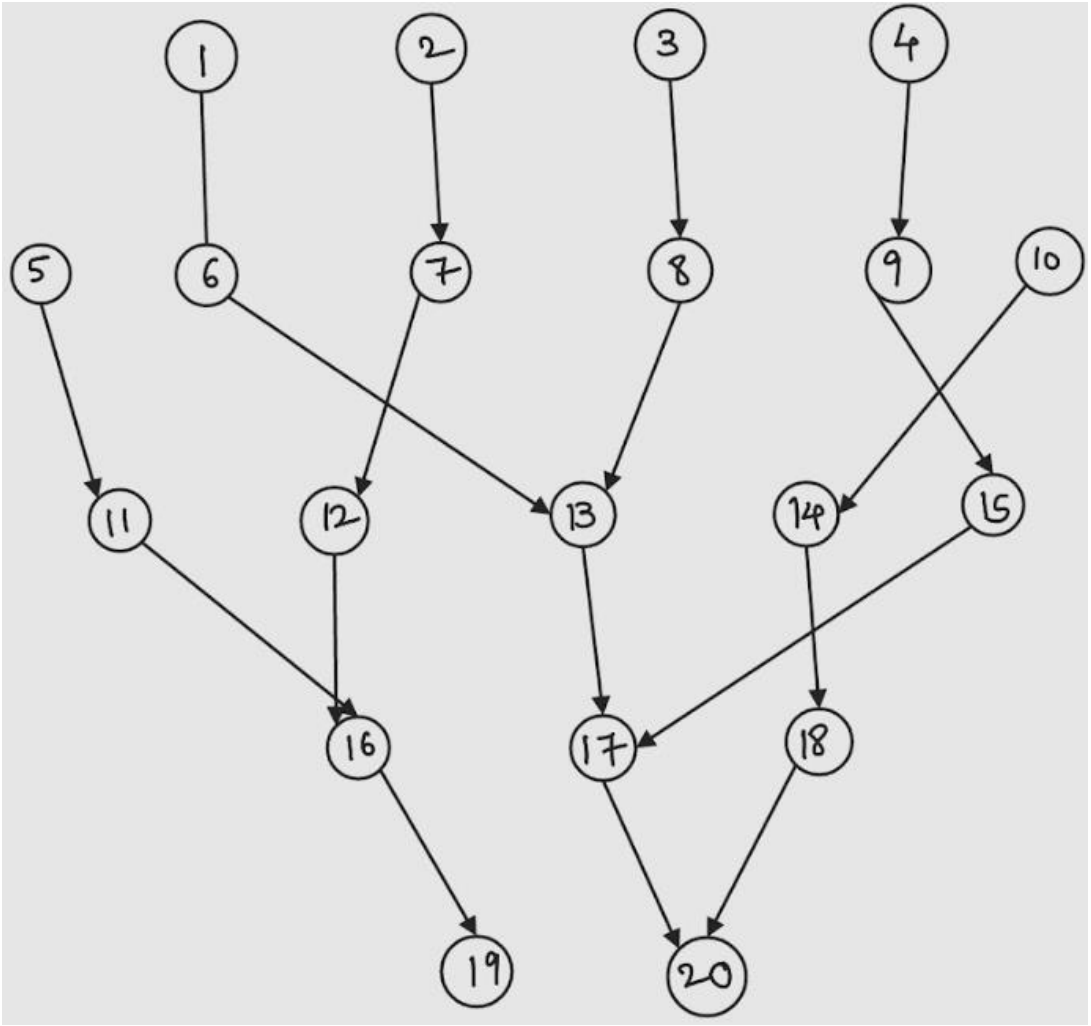
Task	Power	Time	Energy
11	3	4	12
12	5	4	20
13	2	6	12
14	1.5	5	7.5
15	3	2	6
16	5	5	25
17	2	4	8
18	3	6	18
19	5	6	30
20	1.5	6	9

Manual Calculation of Energy Consumption: Final

Task	Power	Time	Energy
1	1.5	6	9
2	1.5	6	9
3	2	6	12
4	1.5	6	9
5	2	7	14
6	5	2	10
7	1.5	6	9
8	5	6	30
9	1.5	4	6
10	3	6	18

Task	Power	Time	Energy
11	3	4	12
12	3	4	12
13	2	6	12
14	1.5	6	9
15	5	2	10
16	1.5	5	7.5
17	1.5	3	4.5
18	5	6	30
19	2	6	12
20	3	6	18

Task Graph 5



Task	Core 1	Core 2	Core 3	Task	Core 1	Core 2	Core 3
1	9	7	5	11	7	6	5
2	8	6	5	12	8	7	4
3	6	5	4	13	9	8	6
4	7	5	3	14	6	6	5
5	5	4	2	15	4	3	2
6	7	6	4	16	6	5	4
7	8	5	3	17	8	7	6
8	6	4	2	18	5	4	3
9	5	3	2	19	5	4	2
10	7	4	2	20	9	8	6

$$T_{max} = 27 \qquad \begin{cases} T^S = 3; \\ T^C = 2; \\ T^R = 1; \end{cases} \qquad \begin{cases} P_1 = 2; \\ P_2 = 3; \\ P_3 = 5; \\ P_s = 1.5; \end{cases}$$

Output for Initial Scheduling

```
Initial schedule:
Task1: Local Core number 3, The start time is: 0,The finish time is: 5
Task3: Local Core number 2, The start time is: 0,The finish time is: 5
Task6: Local Core number 3, The start time is: 5,The finish time is: 9
Task2: Cloud, The start time is: 0,The finish time is: 6
Task8: Local Core number 2, The start time is: 5,The finish time is: 9
Task4: Local Core number 1, The start time is: 0,The finish time is: 7
Task13: Local Core number 3, The start time is: 9,The finish time is: 15
Task10: Cloud, The start time is: 3,The finish time is: 9
Task9: Local Core number 1, The start time is: 7,The finish time is: 12
Task7: Cloud, The start time is: 6,The finish time is: 12
Task5: Local Core number 2, The start time is: 9,The finish time is: 13
Task15: Local Core number 1, The start time is: 12,The finish time is: 16
Task14: Cloud, The start time is: 9,The finish time is: 15
Task12: Cloud, The start time is: 12,The finish time is: 18
Task17: Local Core number 3, The start time is: 16,The finish time is: 22
Task11: Local Core number 2, The start time is: 13,The finish time is: 19
Task18: Local Core number 1, The start time is: 16,The finish time is: 21
Task16: Local Core number 2, The start time is: 19,The finish time is: 24
Task20: Local Core number 3, The start time is: 22,The finish time is: 28
Task19: Local Core number 2, The start time is: 24,The finish time is: 28
 The total energy is: 283.5
 The completion time is: 28
```

Output for final Scheduling

```
After all of Task Migration:
Task1: Local Core number 3, The start time is: 0,The finish time is: 5
Task3: Local Core number 2, The start time is: 0,The finish time is: 5
Task6: Local Core number 3, The start time is: 5,The finish time is: 9
Task2: Cloud, The start time is: 0,The finish time is: 6
Task8: Local Core number 3, The start time is: 9,The finish time is: 11
Task4: Local Core number 1, The start time is: 0,The finish time is: 7
Task13: Local Core number 3, The start time is: 11,The finish time is: 17
Task10: Cloud, The start time is: 3,The finish time is: 9
Task9: Local Core number 2, The start time is: 7,The finish time is: 10
Task7: Cloud, The start time is: 6,The finish time is: 12
Task5: Local Core number 1, The start time is: 7,The finish time is: 12
Task15: Local Core number 1, The start time is: 12,The finish time is: 16
Task14: Cloud, The start time is: 9,The finish time is: 15
Task12: Cloud, The start time is: 12,The finish time is: 18
Task17: Cloud, The start time is: 17,The finish time is: 23
Task11: Local Core number 2, The start time is: 12,The finish time is: 18
Task18: Local Core number 1, The start time is: 16,The finish time is: 21
Task16: Local Core number 2, The start time is: 18,The finish time is: 23
Task20: Cloud, The start time is: 21,The finish time is: 27
Task19: Local Core number 3, The start time is: 23,The finish time is: 25
 The total energy is: 225.5
 The completion time is: 27
The running time of initial schedule of Graph 2 is 38 ms
```

Manual Calculation of Energy Consumption: Initial

Task	Power	Time	Energy
1	5	5	25
2	3	5	15
3	5	4	20
4	1.5	6	9
5	2	4	8
6	5	7	35
7	1.5	6	9
8	2	6	12
9	1.5	5	7.5
10	3	4	12

Task	Power	Time	Energy
11	2	4	8
12	1.5	6	9
13	1.5	6	9
14	5	6	30
15	3	6	18
16	2	5	10
17	3	5	15
18	5	6	30
19	3	6	30
20	3	6	18

Manual Calculation of Energy Consumption: Final

Task	Power	Time	Energy
1	5	5	25
2	3	5	15
3	5	4	20
4	1.5	6	9
5	5	2	10
6	2	7	14
7	5	6	30
8	1.5	6	9
9	3	3	9
10	1.5	6	9

Task	Power	Time	Energy
11	2	5	10
12	2	4	8
13	1.5	6	9
14	1.5	6	9
15	1.5	6	9
16	3	5	15
17	2	2	4
18	3	6	18
19	1.5	2	10
20	5	2	10

Conclusion:

- It can be inferred by the outputs of the code that the Energy Consumed by Initial scheduling is significantly more than that of the Final Scheduling.
- Moreover, the final scheduling takes more time in some cases but compensates in the form of total energy saving.

References:

- [1] X. Lin, Y. Wang, Q. Xie and M. Pedram, "Energy and Performance-Aware Task Scheduling in a Mobile Cloud Computing Environment," 2014 IEEE 7th International Conference on Cloud Computing, Anchorage, AK, 2014, pp. 192-199, doi: 10.1109/CLOUD.2014.35.
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